Possible Martian Obliquity Histories

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The climate of Mars is strongly influenced by the changing patterns of insolation induced by changes in the tilt of the rotation axis or obliquity. The obliquity of Mars changes as a result of torques exerted by the Sun on the aspherical figure of Mars. The shape of Mars is predominantly determined by rotational flattening, but surface loading by volcanism (i.e. Tharsis) and volatiles (polar caps) also contribute. Thus, the obliquity history of Mars is coupled to changes in its climate, and vice versa. During periods of high obliquity, volatiles migrate equatorward, resulting in changes in the planet's oblateness. Obliquity variations are large and chaotic even when changes in the shape of the planet are ignored. In order to assess the effects of obliquity-oblateness feedback, we consider the coupled dynamics also taking into account the response of the solid planet to variations in volatile load. For orbital forcing we rely on the results of our recent, accurate numerical integration of the Solar System. The deformation of Mars is decomposed into two loading contributions due to volatiles and rotation. The shape of the planet is assumed to relax to an equilibrium (hydrostatic) shape at different rates under each load. We model the response of volatile distribution to obliquity changes through a parameterization based on recent GCM results. Using many forward integrations, we present constraints on the past evolution of Martian obliquity for the past 100 million years under a variety of assumptions.